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PRELIMINARY EVALUATION OF PORTABLE AVIATION OXYGEN SYSTEMS

By

Jay C. Bisgard
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Frank S. Pettyjohn

July 1973

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

Fort Rucker, Alabama 36360

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The problem was to determine the requirements for portable aviation oxygen systems during Army high altitude rescue and medical evacuation missions, and then to determine the necessity for R&D efforts by evaluating the potential of currently available system components to fulfill the identified requirements. This preliminary report is a record of USAARL's involvement in the area of Army aviation oxygen systems to include researching the background to achieve a proper direction for study, selection of promising systems for altitude chamber evaluation, study results, conclusions, and feasible recommendations. It was found that immediate Army requirements can be satisfied by currently available military and commercial oxygen system components. Prior to procurement approval, however, the recommended systems should be obtained for field testing by three operational rescue units, the results of which will provide the basis for the final report of this study. Although an R&D effort is not absolutely required, a short term effort would be desirable if limited to modification of prototype components to maximize their potentials while decreasing their ultimate costs.

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Chlorate Candle Oxygen Systems						
Therapeutic Oxygen Systems						
Oxygen Regulators						
Oxygen Marks						

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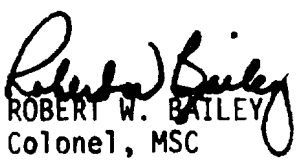
ABSTRACT

This study was conducted to establish the requirements for portable aviation oxygen systems during Army high altitude rescue and medical evacuation missions, and then to determine the need for additional R&D efforts by evaluating the potential of currently available system components to fulfill the identified requirements. This preliminary report is a record of USAARL's involvement in the area of Army aviation oxygen systems to include researching the background to achieve a proper direction for study, selection of promising systems for altitude chamber evaluation, study results, conclusions, and feasible recommendations. It was found that immediate Army requirements can be satisfied by currently available military and commercial oxygen system components. Prior to standardization and procurement action the best qualified system should be obtained for field testing by three operational rescue units, the results of which will provide the basis for the final report of this study. Although minimal R&D effort is required the short term research effort will be limited to modification of prototype components to maximize their life support potentials while decreasing their ultimate costs.



ROBERT W. BAILEY
Colonel, MSC
Commanding

PRELIMINARY EVALUATION OF PORTABLE AVIATION OXYGEN SYSTEMS

INTRODUCTION

PROBLEM

In June 1972, the Commanding General, US Army Alaska (USARAL) stated an urgent requirement for five oxygen systems for use aboard Army helicopters involved in high altitude rescue and medical evacuation missions. In December 1972, OACS Force Development responded to that requirement with a request to USACDC to develop a statement of Required Operational Capability (ROC). In April 1973, The Surgeon General tasked the US Army Aeromedical Research Laboratory (USAARL) to provide answers to the following questions concerning the proposed ROC:

1. Will one system or two separate systems be needed to meet the Army's requirements?

2. Will it be possible to meet the requirement with standard equipment or equipment under development by other services?

3. Will it be possible to meet the requirement with commercial off-the-shelf equipment?

4. Will an R&D effort be necessary to develop a system in order to meet the requirement.

BACKGROUND

The Bioengineering and Evaluation Division, USAARL, studied the USARAL mission and determined that three separate oxygen system requirements must be fulfilled:

1. It must be a lightweight, portable, in-flight system capable of providing adequate oxygen to as many as six aircrewmembers using standard military masks at altitudes up to 20,000 feet for approximately three hours.

2. It must provide a walk-around system capable of providing adequate oxygen to an individual rescuer wearing a standard military mask and working on the ground or in-flight at altitudes up to 20,000 feet for approximately thirty minutes.

3. It must also include a portable patient therapeutic system compatible with a positive pressure ventilation device and capable of providing adequate oxygen to a patient on the ground or in-flight for approximately two hours.

A complete review of the literature pertaining to currently available portable aviation oxygen systems revealed that there are a number of systems which could possibly fulfill one or more of the above requirements. The most promising of these systems was obtained by USAARL and subjected to careful evaluation, including tests in the Fort Rucker altitude chamber.

The objectives of this preliminary evaluation were: (1) determine the capability of each system to fulfill Army requirements through assessment of both static and performance characteristics; (2) determine the relative acceptability of the systems for operational field evaluation through objective comparison of system characteristics; and (3) determine the necessity or feasibility of R&D efforts directed toward modification of available systems or creation of new ones.

METHODS AND MATERIALS

PROCEDURES

The static characteristics of each oxygen system were assessed using the format exemplified in Appendix I. Performance testing was accomplished with two volunteers using each in-flight and walk-around oxygen system at altitudes of 10,000 feet and 20,000 feet in the Fort Rucker altitude chamber following the profile shown in Figure 1. Each therapeutic oxygen system was used by two individuals on the ground and at 10,000 feet in the altitude chamber.

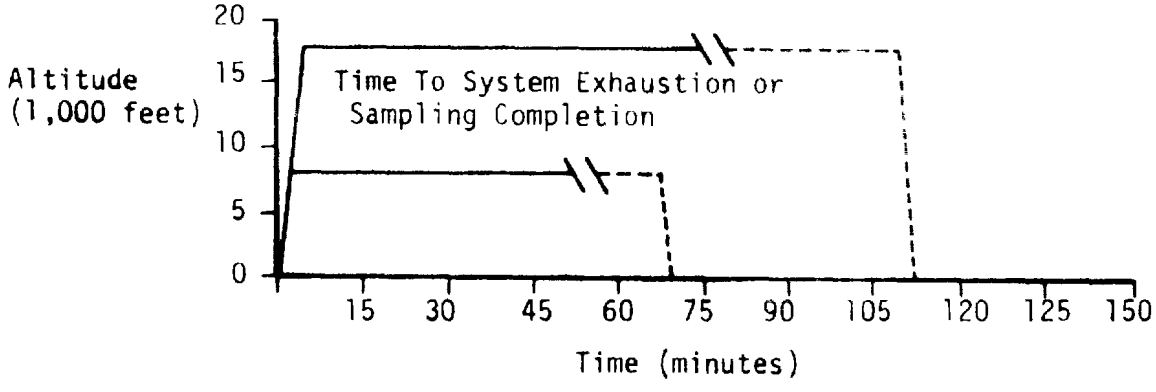


Figure 1. Experimental Flight Profile

Each individual wore the mask compatible with the system under evaluation. The mask was modified to allow the inhaled gases to be monitored

by a Sensorlabs IL 404 oxygen alarm, and to allow the exhaled gases to be directed through a Franz Mueller gas meter. The gasmeter collected 0.6% samples of expired volumes in Mueller bags, beginning at ground level for therapeutic systems, and at 10,000 feet for the other systems. Sample collection was continued for three consecutive fifteen minute periods. Each mask was then disconnected from the oxygen source for one fifteen minute period at 10,000 feet and for one five minute period at 20,000 feet, in order to provide test control samples. Flow durations for those systems not exhausted by the end of the sampling period were calculated from measurements of amounts of oxygen used and reservoir capacities. Barometric pressure and temperature readings were recorded throughout the sampling periods. Mueller meter readings were recorded for total expired volumes and for five tidal volumes during each sample period; these values allowed calculation of average tidal volumes and total respirations. The expired air in the Mueller bags was dried and the oxygen percentages were determined using a Beckman F2 oxygen analyzer. Knowledge of the total mask and anatomic dead space allowed calculation of the relative volumes contributed by true expiratory air and dead space air according to the following formulae:

$$\frac{V_T}{\bar{V}} = R$$

$$\bar{V}_T - (RV_{DS}) = V_E$$

where:

V_T = Total expired volume (dry)

$\bar{V}$ = Average tidal volume (dry)

V_{DS} = Volume of mask and anatomic dead space (dry)

V_E = Volume of true expiratory air (dry)

R = Number of respirations during sample period

Fifteen minute average expiratory oxygen pressures which reflected alveolar oxygen tensions were then determined using the following formulae:

$$\%E_{O_2} = \frac{V_T \%T_{O_2} - V_D \%D_{O_2}}{V_E}$$

$$P_{E_{O_2}} = \%E_{O_2} \cdot P_E$$

where:

$\%T_{O_2}$ = Percent oxygen concentration in Mueller bag

$V_D = RV_{DS}$ = Total dead space volume (dry)

$\%D_{O_2}$ = Percent oxygen concentration in V_D

$\%E_{O_2}$ = Percent oxygen concentration in V_E

$P_{E_{O_2}}$ = Pressure of expiratory oxygen

$P_E = P_B - 47$ = Total pressure of expiratory gases (dry)

DESIGN

Point values for recorded static and performance data were assigned using the scales contained in Appendix II. The point values were placed in the evaluation matrix and multiplied by the weighting factors (Appendix III). The weighting factors were determined by a board of three US Army aviators and two US Army flight surgeons. Total scores were summed for each system. The greater the weighted evaluation score, the greater the relative acceptability of the oxygen system for US Army aviation needs. The perfect system would have a maximum score of 426, while a system judged unsafe or unable to maintain adequate oxygenation would have been unacceptable, regardless of its total score.

RESULTS

IN-FLIGHT SYSTEMS

Two in-flight systems were evaluated: one was the prototype Army high pressure gaseous system described in Appendix IV and the other was the prototype Air Force chlorate candle oxygen supply system described

in Appendix V. The high pressure gaseous system was not available at Fort Rucker, but static and performance characteristics were assessable using information available in Appendix IV. The total score for the gaseous system was 310, while the total score for the chlorate candle supply system combined with torso mounted regulators and MS22001 masks was 393.

The chlorate candle system was evaluated with two different torso mounted regulators: the Air Force CRU-66/A pressure-demand regulator and the Robertshaw torso mounted diluter-demand regulator described in Appendix VI. Both regulators delivered adequate amounts of oxygen to the users, but the CRU-66/A was felt to be unsatisfactory for Army use for the following reasons: (1) Pressure breathing is not required for flight below an altitude of 34,000 feet. (2) Regulator function was highly influenced by regulator orientation and the percent oxygen delivered has been shown by Air Force tests to vary from 6-80% at flow rates from 1-10 LPM at 10,000 feet. (3) The regulator was not designed for oxygen economy and consumed oxygen in far greater quantities than those necessary to maintain adequate oxygenation. The Robertshaw regulator overcame the objections to the CRU-66/A, but one of the two regulators tested was apparently out of calibration during the initial tests. The regulators were returned to the factory for recalibration and installation of an aneroid dilution control mechanism, following which both regulators were retested and found to function well.

WALK-AROUND SYSTEMS

Three walk-around systems were evaluated: one was a high pressure gaseous system and two were low pressure gaseous systems. The high pressure system consisted of a 21 cubic foot cylinder, an A-12 diluter-demand regulator and an MS22001 mask; the total score for the system was 348. One low pressure system was the current Air Force standard system consisting of an A-6 cylinder, an A-13 demand regulator and an MS22001 mask; the total score for the system was 414. The other low pressure system was assembled at USAARL and is shown in Appendix VII; the total score for the system was 423. Although there is a small difference between the scores of the low pressure systems, it should be noted that the system with the lower score did not have a dilution capability and wasted large quantities of oxygen, resulting in flow times which varied from 16 to 23 minutes. In contrast, the flow times of the system utilizing the Robertshaw diluter-demand regulator varied from 33 to 35 minutes at 10,000 feet and 45 to 48 minutes at 20,000 feet.

One additional high pressure gaseous system, the Robertshaw-Blume system, was initially considered for possible service as both an in-flight and a walk-around system.[1] The system was felt to be unsatisfactory for Army aviation use and did not undergo altitude chamber evaluation for the following reasons: (1) The system was designed for use

by mountain climbers acclimatized to altitudes in excess of 10,000 feet and the regulator maintained inspiratory oxygen pressures equivalent to 17,000 - 18,000 feet. (2) The system weight (18.5 lbs) was excessive for walk-around use.

PATIENT THERAPEUTIC SYSTEMS

One patient therapeutic, low pressure, gaseous oxygen system was evaluated. The system was comprised of the walk-around oxygen source described in Appendix VII coupled with the Robertshaw medical demand valve and mask Model 4201, pressure reducer Model 4202; the total score for the system was 414.

An Air Force continuous flow liquid oxygen (LOX) system was initially considered for use as a patient therapeutic system. LOX was felt to be unsatisfactory for Army aviation use and the system did not undergo altitude chamber evaluation for the following reasons: (1) LOX is not available in the Army. (2) The intermittent requirements for oxygen in Army aviation would justify neither the procurement of expensive LOX generation and storage equipment, nor the training of the technicians required to utilize and maintain such equipment. (3) LOX would pose an unacceptable hazard in the Army aviation environment.

Two chlorate candle systems were also initially considered for use as patient therapeutic systems: one was the Scott Med-Ox Duo-Pak and the other was the Air Force CRU-74/P oxygen supply. The major deficiency of these systems was that continuous flow systems cannot be used to ventilate an apneic patient without resorting to an AMBU bag type resuscitator. An AMBU bag was found to maintain alveolar oxygen pressures of approximately 153 mm Hg at sea level, 81 mm Hg at 10,000 feet and 62 mm Hg at 15,000 feet due to one way inlet valve allowing ambient air dilution. In addition to maintaining low alveolar oxygen pressures, another shortcoming is the physical effort required to adequately ventilate an apneic patient for periods in excess of a few minutes. For these reasons, continuous flow systems were felt to be unsatisfactory for patient therapeutic purposes in Army aviation.

Type System	Crude Data Score	CHAMBER EVALUATION Cylinder	Regulator	Oxygen Mask	Remarks
I. INFLIGHT					
1) Prototype USAF Chlorate Candle Low Pressure A/A 23S-1	393	A-6	USAF CRU-66/A Pressure Demand	M 22001	Regulator functions highly influenced by orientation; poor O_2 economy
2) Prototype USAF Chlorate Candle Low Pressure A/A 23S-1	393	A-6	RobertShaw Torso Mount Diluter Demand	M 22001	Operates any orientation; O_2 economy
3) Prototype USA High Pressure Gas	310	NOT AVAILABLE FOR CHAMBER TEST			Static and performance characteristics assessed by information in Appendix IV
II. WALK-AROUND					
4) High Pressure Gas	348	21 CUFT	A-12 Demand Diluter	M 22001	High pressure hazard
5) Low Pressure Gas USAF	414	A-6	A-13 Demand	M 22001	No diluter capability; O_2 wastage
6) Low Pressure Gas, USAARL	423	A-6	RobertShaw Torso Mount Type Diluter Demand Bendix FR100 Pressure Reducer	M 22001	O_2 conserving; low pressure
7) RobertShaw Blume High Pressure	---	NOT EVALUATED IN CHAMBER			System for use by acclimatized personnel only (mountain climbers): excess weight
III. PATIENT THERAPEUTIC					
8) Low Pressure Gas	414	A-6	RobertShaw Medical Demand 4201 RobertShaw Pressure Reducer 4202	RobertShaw Mask	Positive pressure ventilation; maintains alveolar O_2; no physical effort required
9) Liquid Oxygen (LOX) Continuous Flow	---	NOT EVALUATED IN CHAMBER		------	LOX not available in Army; unacceptable hazard in Army aviation environment
10) Scott Med-Ox Duo-Pack Chlorate Candle System	---	Continuous flow systems; required AMBU type resuscitator to ventilate apneic patient			Inability to maintain alveolar O_2 due to ambu inlet valve; causes activation of blow-by safety valve; this effect cannot be assessed externally
11) USAF CRU-74/P Single Chlorate Candle System	---	Continuous flow systems; required AMBU type resuscitator to ventilate apneic patient			Inability to maintain alveolar O_2 due to ambu inlet valve; causes activation of blow-by safety valve; this effect cannot be assessed externally

Figure 2. Data Summary

DISCUSSION OF RESULTS

The sodium chlorate candle possesses a number of characteristics which make it a particularly desirable source of oxygen in the Army aviation environment. It has been shown to be rugged, highly dependable and extremely safe. It weighs less than comparable high pressure cylinders, produces oxygen which easily meets military aviation requirements, and is economical when mission requirements necessitate intermittent, sudden demands for oxygen. The ease of portability, durability and indefinite storage life of the chlorate candle make it possible to stockpile candles anywhere in the world, or to carry extra candles on prolonged missions in remote areas where there would be no sources of gaseous oxygen or LOX. The cost per use of the prototype Air Force disposable chlorate candle is expected to be approximately $30 per manhour, but forthcoming improvements in reusable candle design and production methods can be expected to reduce this cost considerably, perhaps to $5.00 per manhour or lower.

The A/A 23S-1 chlorate candle supply system requires only minimal maintenance which can easily be accomplished by a crew chief using common tools. The system can also be used to recharge low pressure cylinders. This feature allows easy compatibility with low pressure walk-around and patient therapeutic systems. It would, therefore, be possible to use chlorate candles as the only source of breathing oxygen in Army aviation. A typical high altitude rescue mission could then be envisioned in which a loaded, portable, chlorate candle supply system is placed aboard a helicopter upon receipt of the mission. The system is used in-flight by both aircrewmembers and rescuers. Walk-around cylinders are charged from the system while en route to the rescue site. Rescuers connect to the walk-around cylinders on site and use them until they are empty, at which time they reconnect to the in-flight system where they remain until the walk-around cylinders are recharged, or until supplemental oxygen is no longer required. Meanwhile the patient uses oxygen from a walk-around source until the cylinder is empty, and is then connected to the in-flight system.

In the type of operation envisioned above, the advantages of the torso mounted regulator over the panel mounted variety include smaller size and weight, portability, cost and convenience. Like the chlorate candle, the torso mounted regulator is rugged and dependable.

The MS22001 mask was used in all tests of in-flight and walk-around systems. This mask has several design features which make it relatively undesirable. The inhalation valves are very prone to stick in the open position, or to become unseated from the silicone rubber face piece. When either of these situations occurs with one or both valves, exhalation becomes impossible. The presence of two inhalation valves

doubles the probability of such occurrences. When the mask is used under conditions in which perspiration or water vapor condensation can collect in the mask, the dependent position of the exhalation valve leads to liquid pooling in and around the valve and consequent sticking. Also, the band across the upper lip becomes very uncomfortable with prolonged wearing of the mask. The standard Air Force MBU-5/P pressure demand mask overcomes all of the above objections to the MS22001 with the exception of moisture pooling around the dependent valve, Appendix III.

The Robertshaw medical demand valve and mask had several advantages over the alternative AMBU bag type resuscitator, including maintenance of higher oxygen pressure in the patient's lungs, relative simplicity of design, smaller size and weight, and ease of operation. The Robertshaw demand valve can also be adapted to the orifice of either an endotracheal tube or a tracheostmy canula. One relative disadvantage is that an inexperienced medical corpsman could produce over inflation and/or pressure damage to the lung parenchyma with the cutoff pressure of 40mm Hg. Modification of the AMBU bag inlet valve to prevent dilution effects would be an alternative solution.

CONCLUSIONS

The following conclusions resulted from this study:

1. Immediate Army requirements for portable aviation oxygen systems can be satisfied by procurement of currently available commercial and military system components.

2. The best available in-flight system is the prototype Air Force A/A 23S-1 oxygen supply system with Robertshaw torso-mounted diluter-demand regulators and Air Force MBU-5/P pressure demand masks.

3. The best available walk-around system is the A-6 low pressure cylinder with a Bendix FR 100 pressure reducer and the same regulator and mask used with the in-flight system.

4. The best available patient therapeutic system is the Robertshaw demand valve and mask connected to either the low pressure walk-around source or the in-flight supply system.

5. R&D efforts are not absolutely necessary, but are especially desirable in three areas:

(a) Modification of the chlorate candle supply system to make it adaptable to other aircraft in the Army inventory.

(b) Decreasing the cost of the chlorate candle through improvement in design and in production methods.

(c) Modification of the demand oxygen mask for aircrewmembers to improve fit and comfort and to eliminate the dependent position of the valve.

RECOMMENDATIONS

In view of the evaluation results and conclusions, the Bioengineering and Evaluation Division, USAARL proposes the following actions and recommendations:

1. Procurement of three prototype Air Force A/A 23S-1 oxygen supply systems, 240 chlorate candles, 24 Robertshaw torso-mounted diluter-demand regulators, 12 low pressure walk-around sources described in Appendix VI 6 Robertshaw medical demand valve and mask assemblies and 24 MBU-5/P pressure-demand oxygen masks.

2. Placement of one complete set of equipment to include one A/A 23S-1 system, 80 chlorate candles, 8 Robertshaw regulators, 4 walk-around sources, 2 medical demand valve and mask assemblies and 8 MBU-5/P masks at each of three field sites for completion of the field evaluation portion of this study. Suggested sites for such field evaluations are Fort Greely, Alaska; Fort Carson, Colorado; and Fort Lewis, Washington.

3. Stipulation in the USAARL procurement contract for the A/A 23S-1 systems that the following minor modifications be included:

(a) The system must be made compatible with forthcoming reusable candles.

(b) The system must include a provision for a remote control panel.

(c) The system must include a pressure reducer at the outlet to insure a delivery pressure of 70 psi.

(d) The system must be capable of restraint and operation while on its side.

4. Development of USAARL monitored Army contracts with MSA Research Corporation, the designer and manufacturer of the A/A 23S-1 system, to speed development of lower cost chlorate candles and new supply systems, perhaps of modular design, which will be adaptable to all Army aircraft and suitable for permanent installation on all aircraft primarily used for aeromedical evacuation.

5. Development of USAARL monitored Army contracts to improve the demand oxygen mask by placing a combination inhalation-exhalation valve in a nondependent postion on a low weight, low profile, well fitting mask.

Although the costs of procurement of the above equipment and of funding short term development efforts can be expected to approach $250,000, perspective should be maintained by considering the fact that the loss of just one UH-1 helicopter and its crew of four due to preventable aircrewmember hypoxia would cost considerably more than this sum. It should also be noted that immediate field requirements for mission essential oxygen equipment will be satisfied by approval of the recommended field evaluations.

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APPENDIX I

OXYGEN SYSTEM CHARACTERISTICS

DATA SHEET I

1. System Number _____

2. Components

   a. Reservoir

   (1) Type _____

   (2) Description _____

   (3) Manufacturer _____

   (4) FSN _____

   b. Regulator

   (1) Type _____

   (2) Description _____

   (3) Manufacturer _____

   (4) FSN _____

   c. Mask

   (1) Type _____

   (2) Description _____

   (3) Manufacturer _____

   (4) FSN _____

3. System Characteristics

   a. Purpose _____

   b. Number Aircrewmen Supported _____

c. Weight

(1) Empty _____ lb

(2) Filled _____ lb

d. Dimensions _____ in

e. Vulnerability and Potential Hazard in Army Environment

(1) Minimal _____

(2) Moderate _____

(3) Unsafe _____

Explain

f. Ease of Maintenance

(1) Maintenance Site

(a) Unit _____

(b) Other _____

(2) Training Requirement

(a) < 1 day

(b) > 1 day

g. Charged Storage Life

(a) Minimal (< 1 week) _____

(b) Moderate (1-52 weeks) _____

(c) INDEF (> 52 weeks) _____

4. Cost Factors

a. Acquisition Costs

(1) Reservoir $ _____

(2) Regulator $_____

(3) Mask $_____

TOTAL $_____

b. Use Costs

(1) Oxygen $_____

(2) Regulator $_____

(3) Mask $_____

TOTAL $_____

c. Maintenance Costs

(1) Tools $_____

(2) Training $_____

(3) Other $_____

TOTAL $_____

APPENDIX II

POINT SCALES FOR CRUDE DATA

I. Characteristic Data:	Points
a. Vulnerability and potential hazard	
(1) Minimal	3
(2) Moderate	1
(3) Unsafe	0
b. Weight (filled) per Crewman	
(1) $\leq$ 15 lbs	3
(2) 15-25 lbs	2
(3) $\geq$ 25 lbs	1
c. A-13 or AMBU Compatibility	
(1) Compatible	2
(2) Incompatible	1
d. Number Crewmen Supported	
(1) Meets Specification	2
(2) Does not meet specification	1
e. Dimensions	
(1) Minimum	2
(2) Maximum	1
f. Maintenance Cost	
(1) Minimum	2
(2) Maximum	1

Characteristic Data:	Points
g. Cost per Use per Crewman	
(1) Minimum	2
(2) Maximum	1
h. Acquisition Cost per Crewman	
(1) Minimum	2
(2) Maximum	1
i. Maintenance Site	
(1) Unit	2
(2) Elsewhere	1
j. Training Required for Maintenance	
(1) < 1 day	2
(2) > 1 day	1
k. Storage Life	
(1) > 52 weeks	3
(2) 1-52 weeks	2
(3) < 1 Week	1
II. Performance Data	
a. Adequate P_{IO_2} at altitude	
(1) Meets specification	3
(2) Does not meet specification	0
b. Too heavy	
(1) No	2
(2) Yes	1

c. Flow Time

(1) Meets specification 2

(2) Does not meet specification 1

d. Simple operation

(1) Yes 2

(2) No 1

e. Limits activity

(1) No 2

(2) Yes 1

f. Too bulky

(1) No 2

(2) Yes 1

g. Noxious odor

(1) No 2

(2) Yes 1

h. Noxious taste

(1) No 2

(2) Yes 1

APPENDIX III

EVALUATION MATRIX

Character Criterion	Potential Hazard	Wt per Crewman	A15 or AMBU Compat	Number CM Supported	Dimensions	Maintenance Cost	Cost per use per Crewman	Acq Cost per Crewman	Maintenance Site	Training Req For Maint	Storage Life	TOTALS
Weight Points	21	17	15	15	13	11	9	7	5	5	3	
Scale Points												
TOTALS												

Performance Criterion		Adeq P_{EO_2} at Alt	Too Heavy	Flow Time	Simple Operation	Limits Activity	Too Bulky	Noxious Odor	Noxious Taste
Weight Points		15	13	9	9	7	5	3	3
SCALE PTS	Subject A								
	Subject B								
	Subject C								
Total Scale Points									
Totals / N									
TOTALS									

TOTAL SCORE

APPENDIX IV

DEPARTMENT OF THE ARMY
222D AVIATION BATTALION
APO SEATTLE 98711

ARDSL

30 August 1972

SUBJECT: Helicopter Oxygen System

THRU: Commanding General
United States Army, Alaska
ATTN: ARAGL-M (LTC Ruskauff)
APO Seattle 98749

TO: AMC Project Office
Life Support Equipment
United States Army Material Command
ATTN: AMCPO-LSE (A.B.C. Davis)
P.O. Box 209
St. Louis, Missouri 63141

1. Army aviation assets in USARAL have long been utilized in search and rescue work throughout the state of Alaska. Due to the type of terrain found here, many of these missions are performed by helicopters above 14,000 feet MSL, requiring oxygen. As a result, a portable oxygen system was constructed within the 222d Aviation Battalion for this purpose.

2. The system is basically the same as that found in the U-21A (Inclosure 2), only it is condensed into a portable unit which can be moved from type helicopters as necessary, i.e., UH-1, CH-47 and CH-54.

3. In July 1972, the system was tested from gound to 20,000 feet and performed flawlessly. Shortly thereafter, this oxygen system was utilized in an actual rescue at 16,000 feet and again with complete success.

4. With the success of the portable oxygen system, it is requested that this system be made available through Army supply channels under one FSN for units engaged in high altitude helicopter operations.

5. This system weighs 148 pounds, it is 40" high, 30" wide and 11¼" deep. Two (2) 64 CF cyls, charged to 1800 PSI, provide oxygen to a pressure reducer which reduces the pressure from 1800 PSI to a constant 400 PSI to the demand regulators. Shutoff valves and pressure gauges are placed in

ARDSL 30 August 1972
SUBJECT: Helicopter Oxygen System

areas of pressure change for monitoring and to enable complete or partial shutdown of the system should an emergency arise. Cylinders are removed for recharging and extra charged cylinders are on hand. Provisions for recharging a walk-around bottle are also incorporated in this system and can be used while the system is in operation or static.

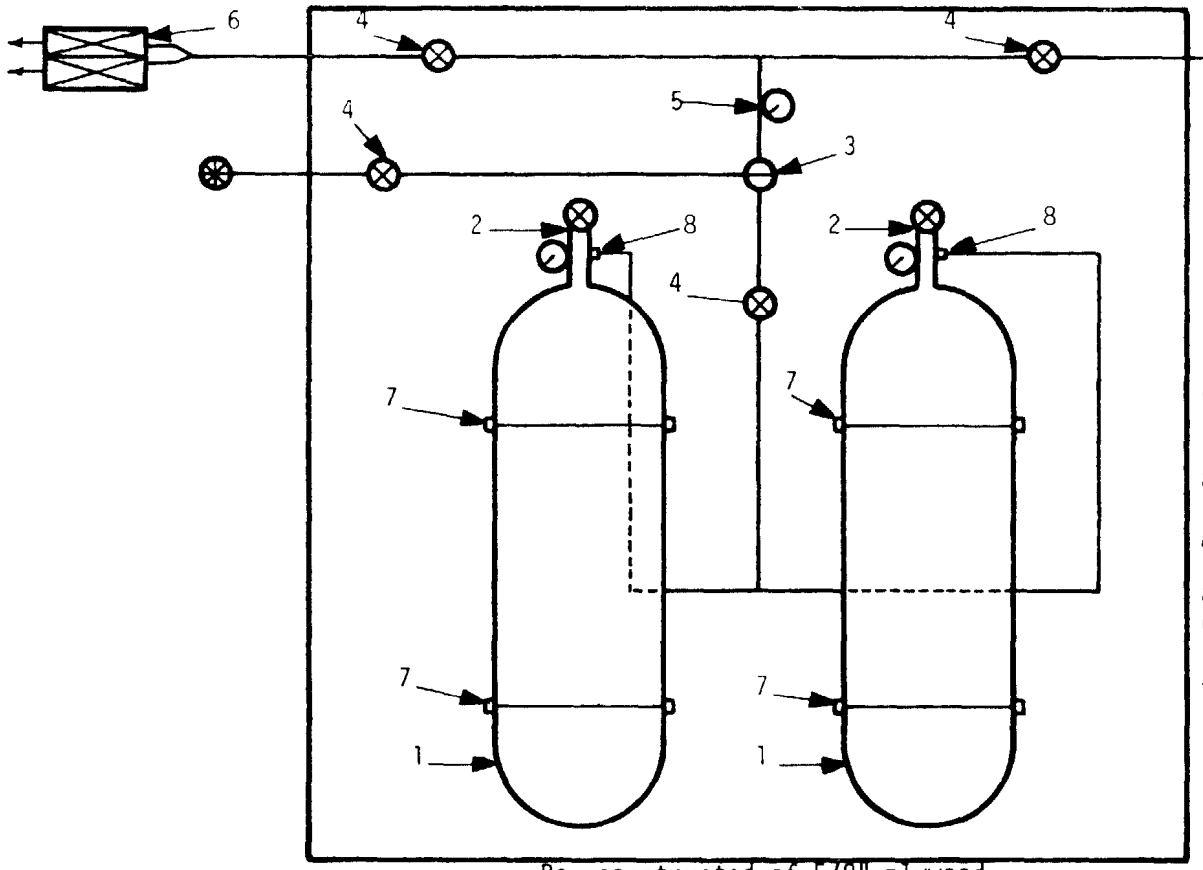
6. A second oxygen system is under construction by this unit and will remain basically the same except that the overall dimensions will be a few inches smaller and provisions to recharge cylinders in the box will be made, giving two methods for recharging.

7. Inclosed is a complete discription of the Portable Oxygen System.

GERALD E. NASH
CW3, AVN
Acft Maint Officer

3 Incl
1. Pictures (4) (Deleted)
2. Diagram, parts
3. Diagram, operating instructions

PORTABLE OXYGEN SYSTEM



Box constructed of 5/8" plywood

1. 8120-122-8988 Cyl, Oxy 2ea
2. 1660-993-5468 Valve, slow open 2ea (come with gauge)
3. 1660-880-3168 Valve, pressure reducer 1ea
4. 1660-932-5169 Valve, slow open 4ea
5. 6680-995-1323 Gauge 1ea
6. 1660-856-0273 Regulator, demand 4ea
7. 1560-089-5847 Bracket 4ea
8. 4730-722-1369 Adapter 2ea

ADDITIONAL ITEMS to support system
8030-889-3534 Tape(as required)
6850-621-1819 Leak detection compound (as required)
4720-781-6768 Hose assy Oxy 24" (as required)
1660-787-8437 Hose assy Oxy 14" (as required)
1660-810-7351 Hose assy Oxy 4ea
Fittings are required to connect system

Gauge

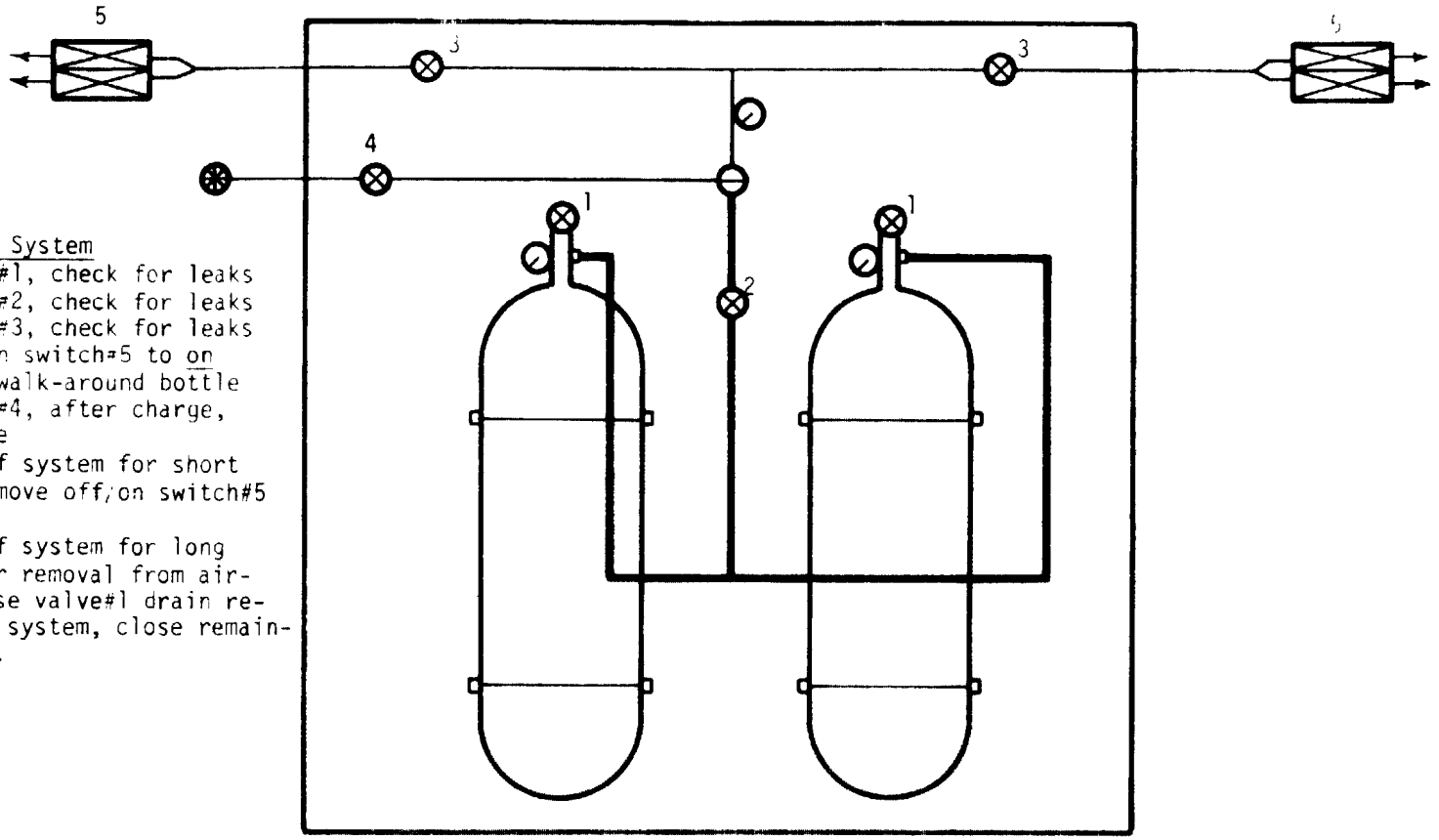
Slow Open Valve

Pressure Reducer (1800 in 400 const out)

Filler Valve

Demand (auto) Flow Regulator

PORTABLE OXYGEN SYSTEM



To Operate System

1. open valve#1, check for leaks
2. open valve#2, check for leaks
3. open valve#3, check for leaks
4. move off/on switch#5 to on
5. to charge walk-around bottle open valve#4, after charge, close valve
6. to shut off system for short duration, move off/on switch#5 to off
7. to shut off system for long duration or removal from aircraft, close valve#1 drain remainder of system, close remaining valves.

Gauge

Slow Open Valve

Pressure Reducer (1800 in 400 const out)

Filler Valve

Demand (auto) flow Regulator

High Pressure

Low Pressure

APPENDIX V

CHARACTERISTICS OF A/A23S-1 CHEMICAL OXYGEN SYSTEM

Introduction

The A/A23S-1 Chemical Oxygen System is currently undergoing final reliability testing and final environmental testing. Both programs are nearly complete and the system is operating as required.

Twelve chlorate candles are attached to a manifold which serves as the structural backbone of the system. Oxygen from the candles is stored in two non-shatterable bottles, from which it is delivered to the crew on demand. A total of 3030 liters is available from the 12 candles at the normal supply rate of 16.85 lpm: the system will automatically meet a demand up to 49.5 lpm. Above the latter flow, manual firing of candles would be expected.

Operation is completely automatic, a candle being actuated when pressure in the system drops to 85 psig. Candles can be manually actuated at any time without upsetting subsequent automatic operation. A light status board indicates number of candles ready for use and gives an internal check on firing mechanism continuity.

The entire system is contained in an alum. box which supports the system for installation in the aircraft and also serves as a housing to direct air flow from two fans through the candle compartment and out a filter on the top. Reaction heat of the candles is removed to maintain acceptable touch temperature on the box exterior. The unit uses aircraft 28 V DC power (~120 watts peak) and feeds oxygen to the aircraft oxygen distribution system.

Candles are replaced with little effort, being attached to the manifold by quick disconnects. The actuation circuit is attached to the top of the candle housing by a bayonet fastener.

General System Characteristics

System criteria are shown in the attached criteria. These criteria have been met by testing.

Reliability

The reliability program is just being completed. It consists of two parts - 2064 actuations without failure to exercise the actuation/control system, and 192 candle firings. The actuations have been completed without failure and we are presently at 120 candles without failure. In addition to the candle firing, pressurization time and total oxygen delivery must meet reliability requirements.

Given successful completion of the remainder of the candle firings, this will demonstrate a system reliability of 75 hours of operation mean time between failures at the 90% confidence level.

Storability of Candles

The candles may be stored for a minimum of 10 years without deterioration. We have tested chlorate candles packaged in a similar fashion after 20 years storage and operation was as originally specified. It is desirable that atmosphere be excluded from the candle proper for best results - this is a function of slight water absorption by the candles. There is no deterioration otherwise.

Maintenance Required

Twelve candles can be replaced within 30 minutes, making the system again ready for operation.

A dryer is used to attain the required moisture level. This has a removable element which can be regenerated by heating, or discarded since it is a pre-packaged unit. Approximately 15 minutes is required to replace the element. A suggested replacement cycle is once every 120 candles.

Blowers are aircraft type with the same type of maintenance care. They can be replaced easily, if required. Two filters for the inlet and outlet air prevent undue dust contamination of the system. These can be cleaned by washing with water and then be reinstalled.

Other maintenance is that associated with any oxygen system that is used repeatedly. Leak testing should be performed occasionally and it may be necessary to replace O-rings at wide intervals.

Operating Instructions

The system requires no attention to maintain oxygen pressure within the storage bottles. If the pressure is over 85 psig, candles will not fire automatically. A candle can be fired manually at any time irrespective of system pressure or point in the automatic cycle. The system can be set for automatic or completely manual operation.

Installation of the system in the aircraft requires that the holddown straps be attached to cargo rings or similar points, that the oxygen line be connected and that the power plug be connected to the aircraft 28 volt source.

As the oxygen is breathed from the system, the pressure will drop. At 85 psig a candle will be fired. If the pressure continues to drop another candle will fire at 65 psig and a 30 second time delay is actuated. If the pressure rises above 65 psig within the 30 seconds, another candle is not fired - if the pressure does not reach 65 psig within 30 seconds, another candle is fired and another 30-second cycle is started. This feature is built into the system to accommodate high oxygen use rates and permit some time for the oxygen pressure to rise.

Initially then, the system can be pressurized with cylinder oxygen to greater than 85 psig to prevent firing the candle. Otherwise, when the system is put on automatic cycle a candle will fire to bring the pressure above that point. A relief valve is set to vent if the system pressure should exceed 450 psig.

Operation of the system is monitored by the display panel. Twelve lights correspond to the 12 candles. When a candle is available for use, its indicator light is on. If circuit continuity is missing so that the candle cannot be fired, or if the candle has been fired, the light is off. (An indicator light also shows when the system is on automatic.) In order to fire a candle manually, a lift snap action switch is operated and a red "reset" light appears. The reset switch must be actuated before another candle can be fired manually, although the system will continue to operate in the automatic mode (assuming it was on automatic mode at the time of the manual firing). This reset feature prevents rapid triggering of candles manually and forces the operator to consider before firing another.

The system is arranged so that the fans turn on automatically when the first candle is fired but remain on until power is interrupted to the system. Blower power is indicated by two press-to-test lights, one for each blower. Blower fuses are installed on the panel board for easy access, as is the main power fuse.

An oxygen pressure gage is installed on the top surface. An oxygen fill line is also available to fill the system or to obtain oxygen from the system if desired.

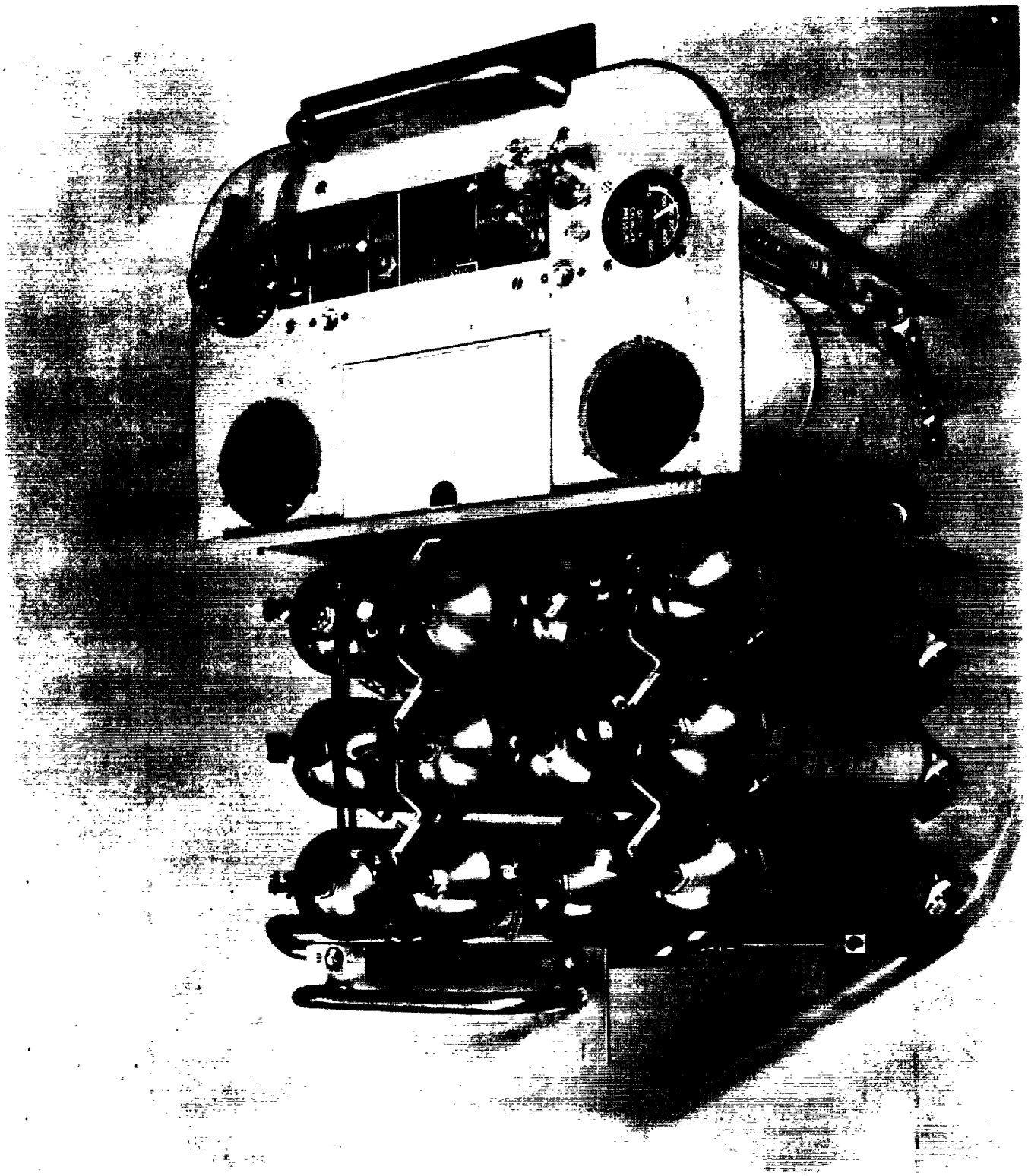
Candles are replaced in the system by removing four friction pins and lifting the system from its box. The lid over the candles is removed by loosening four Dzus fasteners with a screwdriver, exposing the tops of the candle array. Bayonet electrical fasteners are removed and a screwdriver is used to loosen worm screws on bands that hold the candles in place. The candles are then removed by breaking the quick disconnect at the bottom of each candle. Charging is the reverse of this procedure.

When the dryer is removed for servicing the bleed valve should be actuated to reduce pressure in the system to ambient.

Design Characteristics

Crewmen	Seven
Time, Normal Mode	3 hr
O_2 Supply Source	$NaClO_3$ Type Candles
O_2 Supply, Total	3030 liters
O_2 Supply Rates	
Normal Mode	16.85 lpm
Emergency Mode	49.5 lpm
Unit Weight	
Empty	86 lb
Full (12 candles)	146 lb
Dimensions, Overall	24 in. high, 18 in. wide, 25 in. long
Oxygen Generator	
Size	3 in. OD x 14.7 in. long
Weight	5 lb each
Oxygen Purity	per MIL-E-83252
Cl_2	<0.2 ppm
CO	<15 ppm
CO_2	<1000 ppm
Total HC	<0.5%
Particulates	<100 microns
Fibers	<40 x 600 microns
Moisture	<0.02 mg/liter
Total Solids	<1 mg/liter
Storage Tank	Non-shatterable type Store O_2 from one candle
Relief Valve	450-500 psig
Ignition	Electrical, automatic, sequential with manual override
Spent Candle Indication	Thermal and light board

Operating Conditions	
Pressures	
Minimum	50 psig
Maximum	450 psig
Temperatures	-65°F to 120°F
O_2 Outlet Temperature	60°F above ambient max.
Leakage	Disconnects less than 0.01 liter/min
Environmental Conditions	
Temperature	-65°F to +160°F
Relative Humidity	95°F
Atmosphere Exposure	Salt-laden moisture
Particles	Sand and dust
Vibration	Per MIL 810B
Shock	Per MIL 810B
Temperature of Exposed Parts	Less than 60°F above ambient
O_2 Purity	Per MIL-E-83252 except moisture to be no more than 0.02 mg/liter
O_2 Temperature	60°F maximum above ambient (normal mode)
Maintainability	30 min downtime, each task
Reliability	MTBF not less than 75 hours @ 90% confidence level
Power Supply	28 V DC



NO STEP


NO STEP

REGULATOR, OXYGEN, DILUTER DEMAND

CHEST MOUNTED

P/N 900-002-134

ROBERTSHAW CONTROLS COMPANY
Aeronautical and Instrument Division
Anaheim, California

TABLE OF CONTENTS

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Positive Pressure	3
Air Dilution System	4
Relief Valve	5

ILLUSTRATIONS

Figure

1. Schematic, Diluter Regulator 2

INTRODUCTION

The regulator described herein is a diluter-demand regulator intended to be man mounted. The unit, with the addition of pressure breathing, is fully qualified to Lockheed Specification 423556 and has been in service on the S-3A aircraft since early 1972.

REGULATOR ASSEMBLY

The subject regulator is a diluter-demand type designed for torso mounting. The regulator has two modes of operation and a manual means to select the desired mode. In the "Normal" mode the regulator provides air dilution and demand operation. In the "Emergency" mode the regulator provides 100% oxygen and safety pressure. The regulator contains a means to close the air port upon loss of oxygen supply and thus provide user warning by restricting all flow from the regulator. The regulator also has a relief valve to prevent pressure buildup at the outlet and is designed to operate with a supply pressure in the range of 40 to 120 psig.

The major components of the regulator assembly consist of the oxygen regulator, dilution system, relief valve, and a knob for manually selecting either normal or emergency operation. A system schematic of the proposed assembly is shown in Figure 1.

Oxygen Regulator

The oxygen regulator consists of a main valve (1), pilot valve (2), sensing diaphragm (3) and dome (4). The main valve consists of a stem and diaphragm

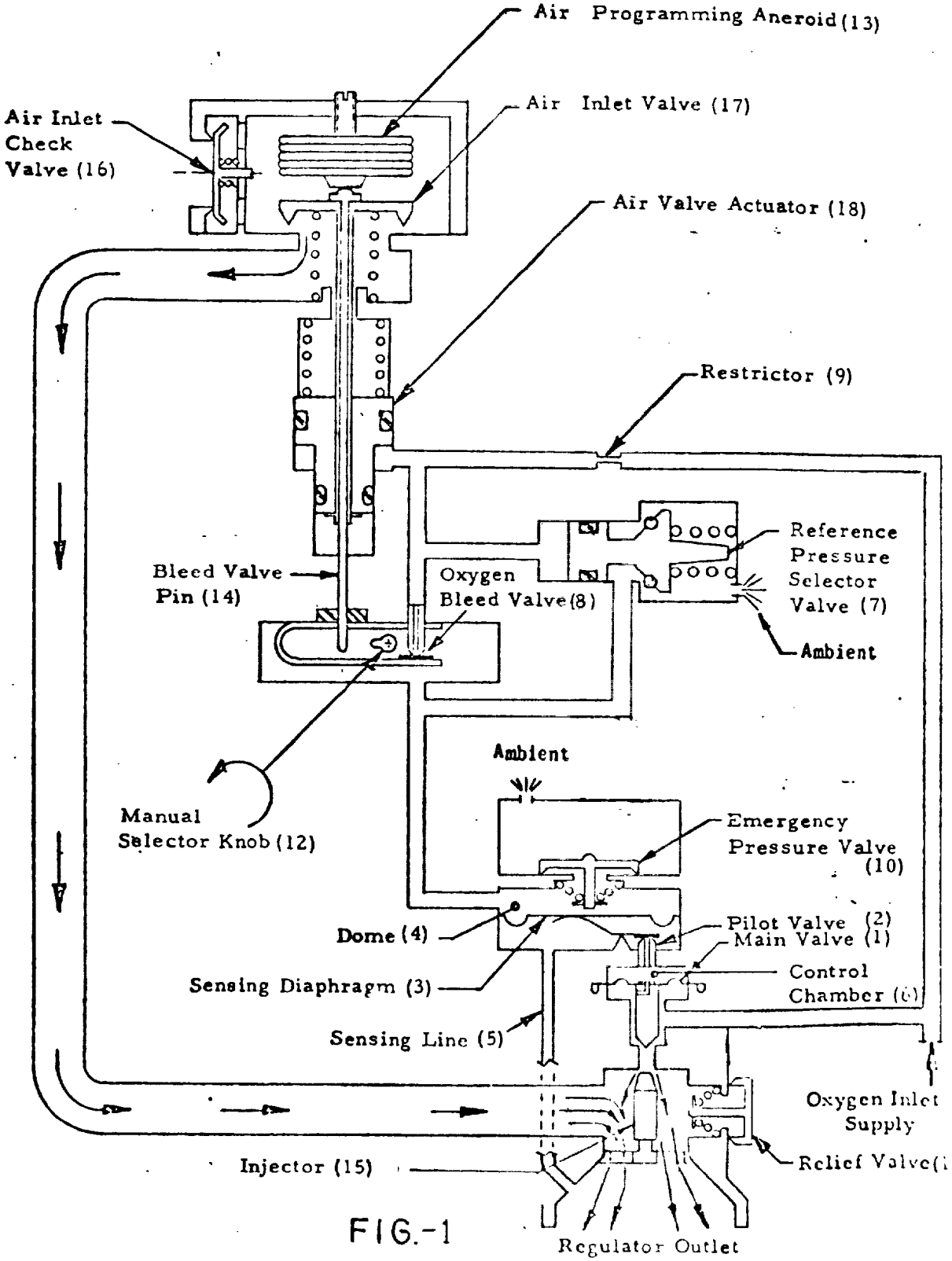


FIG.-1

SCHEMATIC, SYSTEM - MILITARY DILUTER

with a restricted passage connecting both sides of the diaphragm. With the pilot valve closed the pressure on both sides of the diaphragm is supply pressure and the valve is held closed. When flow is demanded from the regulator the suction occurring at the regulator outlet is communicated to the pilot valve chamber by the sensing line (5). This lowering of pressure causes the sensing diaphragm (3) to move in a direction to unseat the paddle and open the pilot valve (2). When flow is initiated through the pilot valve the pressure in the control chamber (6) decays so as to open the main valve (1). The flow will thus be controlled such that the suction at the regulator outlet will be within prescribed limits. When demand ceases the pilot valve and main valve will close.

Positive Pressure

The positive pressure system consists of a reference pressure selector valve (7), oxygen bleed valve (8), restrictor (9) and emergency pressure valve (10). During normal operation the oxygen bleed valve (8) is closed and the pressure exerted on the reference pressure selector valve (7) is equal to supply pressure which holds the valve open so that the passage to the regulator dome (4) is opened to ambient. The regulator thus acts as a demand regulator which requires a suction at the outlet to initiate flow. Moving the manual selector knob (12) to the "Emergency" position opens the oxygen bleed valve (8). The flow from this valve is controlled by restrictor (9) which is preset to a range of approximately 0.1 to 0.4 LPM. Opening of the bleed valve (8) causes the pressure acting on the reference pressure selector valve (7) to decay and the spring therefore moves the valve to a closed position which seals off the ambient reference to the dome (4). The bleed will thus be channeled into the

dome (4) and past emergency pressure valve (10). This valve is spring loaded to hold a pressure in the dome (4) of approximately one inch of water. This dome pressure will act against the sensing diaphragm (3) to open the regulator until the output pressure is increased to an equivalent level, thus providing the safety pressure function.

With the manual selector knob (12) in the "Normal" position the oxygen bleed valve (8) will be opened automatically between 25,000 and 30,000 ft. by the air programming aneroid (13) acting against the bleed valve pin (14). This action provides a positive outlet pressure in the same manner as described above.

Air Dilution System

The air dilution system consists of an injector (15), air intake and altitude programming sections. The injector (15) consists of a spring loaded poppet and seat situated immediately down stream of the main valve. The injector (15) causes the oxygen to form a high velocity jet which in turn indices airflow through the intake system by venturi action. In the 100% mode the poppet opens sufficiently to permit full flow from the main valve.

The air intake system contains an inlet check valve (16) and an air inlet valve (17). The check valve is spring loaded to the closed position. The spring force is calibrated against the cracking pressure level required to induce oxygen flow from the regulator so that proper proportioning of air and oxygen is provided at low flows. The air programming aneroid (13) progressively closes the air inlet valve (17) as altitude is increased thus providing an increasing air enrichment.

The air programming system also contains a piston which is called the air valve actuator (18). When the oxygen bleed valve (8) is closed, this piston is

acted upon by supply pressure so as to allow the air inlet valve (17) to be positioned by the air programming aneroid (13). When the oxygen bleed valve (8) is opened either manually by the manual selector knob (12) or automatically by the action of the air programming aneroid (13) against the bleed valve pin (14), the pressure downstream of the restrictor (9) decays and a spring moves the air valve actuator (18) to contact a shoulder on the air inlet valve shaft (17) and move it to a closed position. This action produces 100% oxygen operation simultaneously with the safety pressure described above. This same actuator closes the air inlet valve (17) upon loss of oxygen supply pressure.

Relief Valve

A relief valve (19) is located in the outlet section of the regulator. It is capable of venting a minimum of 75 LPM at a pressure no greater than 22 inches of water. Leakage of this valve is less than .01 LPM at a pressure of 17 inches of water.

DESIGN FEATURES

Performance

The regulator meets the performance requirements of Lockheed Specification 423556.

Reliability

The design is based on proven concepts utilizing components and techniques which have been proven reliable by past experience.

Oxygen Consumption

Conservation of oxygen supplies is assured by two regulator characteristics. One is the absence of oxygen bleed during "normal" operation. The bleed system

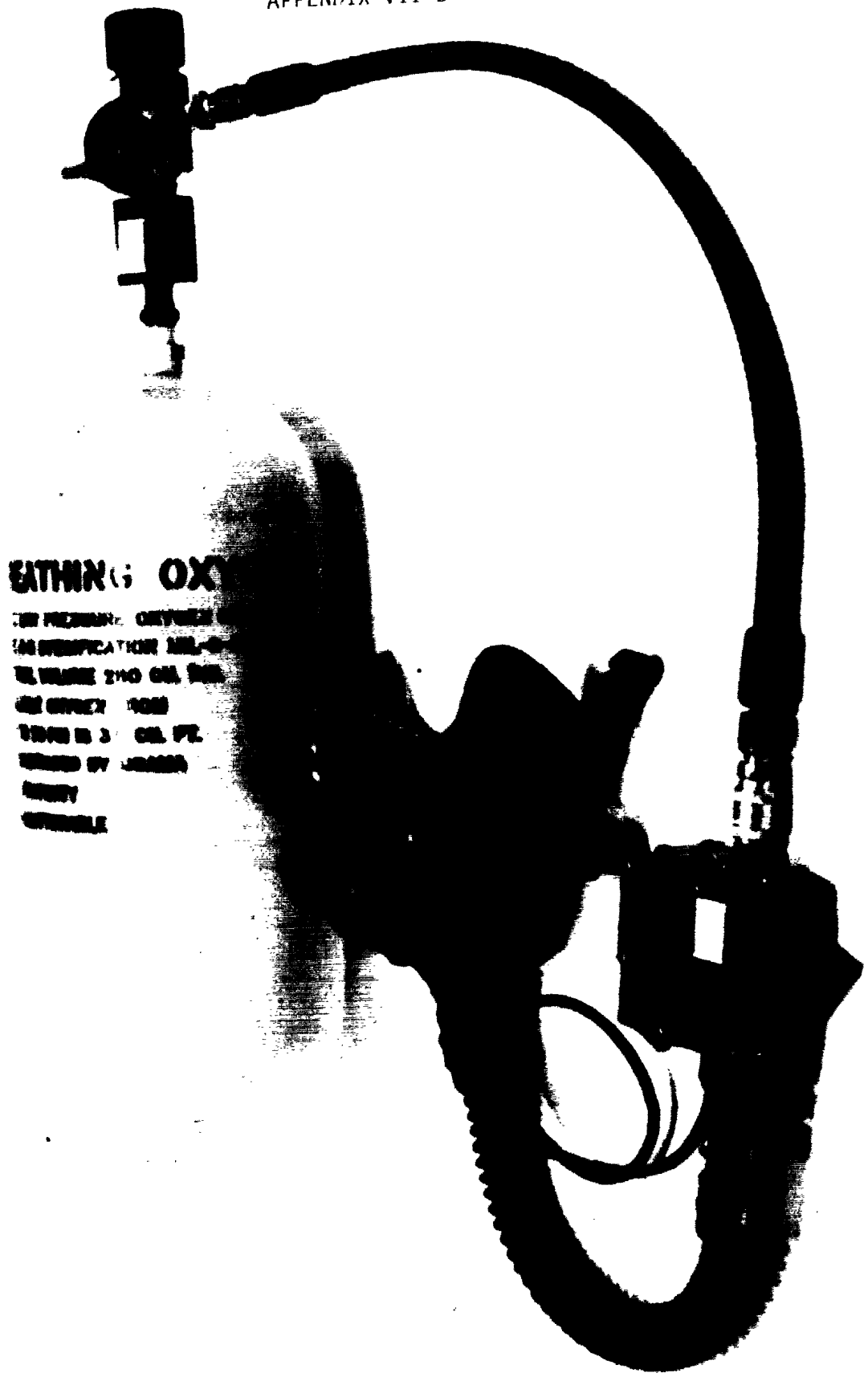
is actuated only when necessary to produce positive pressure operation, thus there is no oxygen loss during standby.

The regulator also features an efficient injector system which minimizes oxygen consumption during "Normal" operation. Consumption rates of a typical regulator are as follows:

Altitude 1,000 Ft.	Consumption Rate Liters Per Hour Per Man*
10	150
15	170
20	135
25	120
30	190

*Based on Breathing Rate of 15 LPM BTPS

APPENDIX VII-A



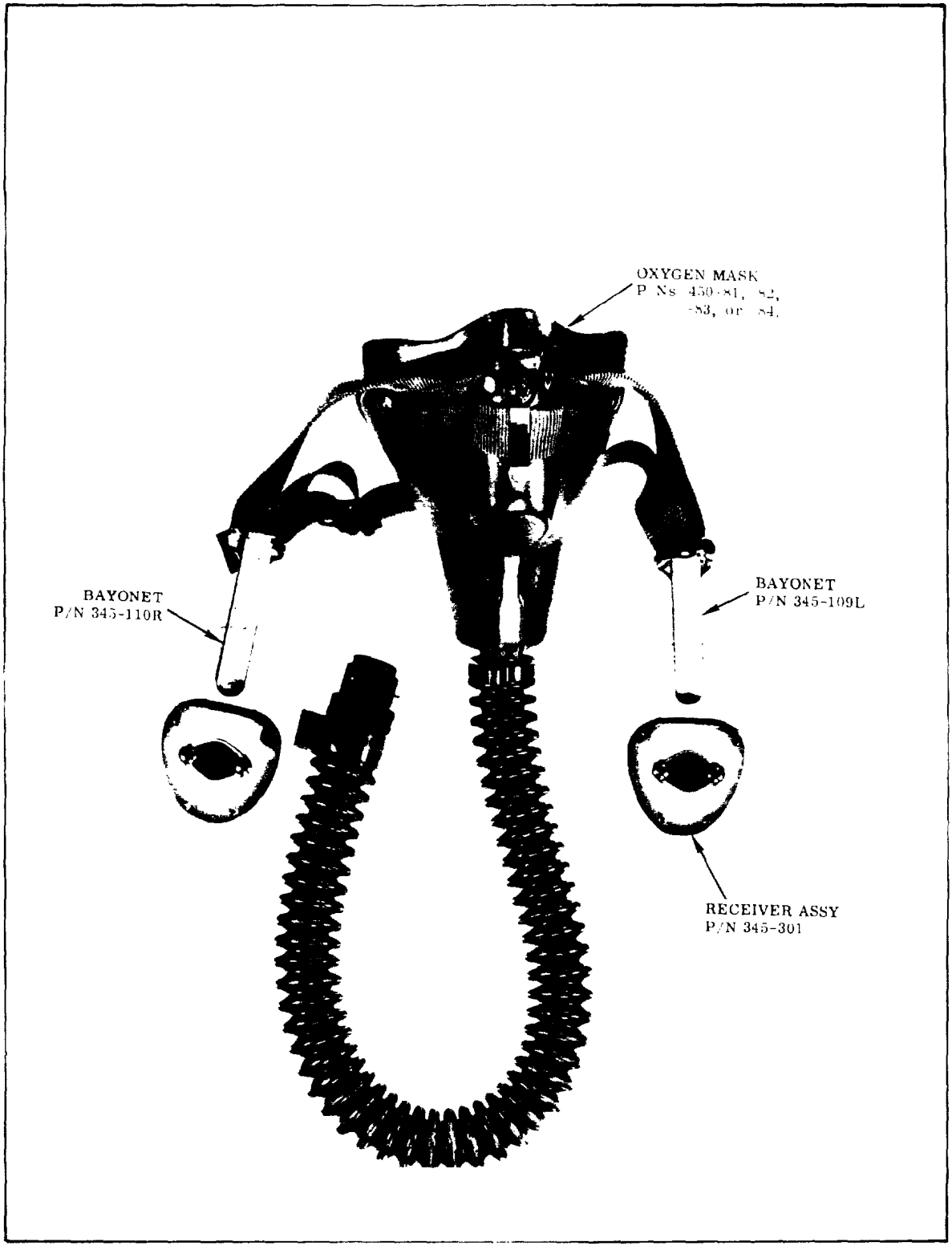


Figure 1-1. Pressure Demand Breathing Oxygen Mask, Type MBU-5/P, and Accessories (sheet 1 of 5)

1-1